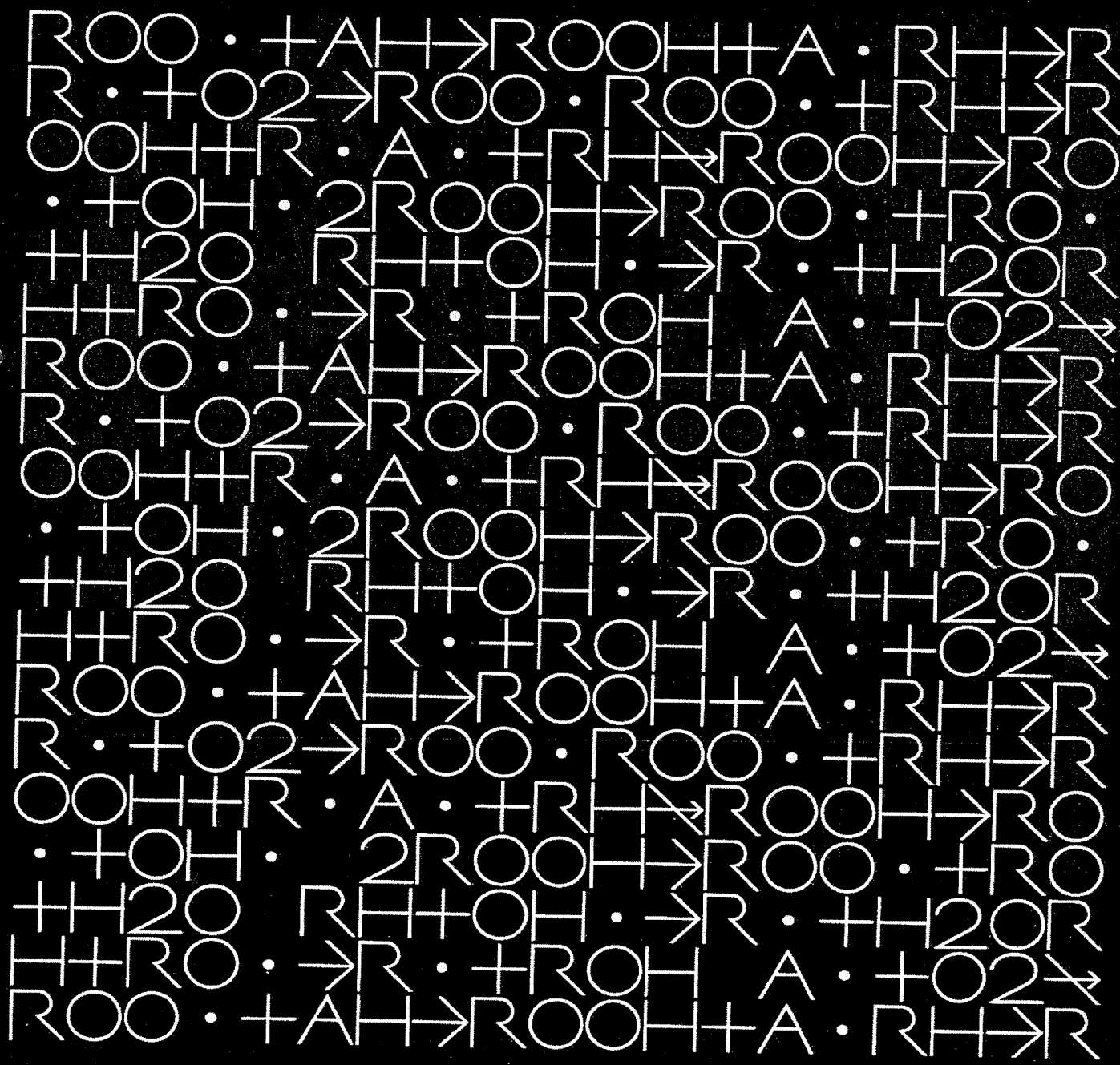
APPENDIX

Irganox® 1010

Antioxidant and
Thermal Stabilizer

CIBA–GEIGY



Irganox® 1010

- **A versatile and highly effective antioxidant for use in a wide variety of substrates**
- **Adds no initial color when compounded into substrates, and retards color development during end use**
- **Protects polymers against thermal degradation during processing**
- **Provides long term resistance to polymer deterioration**
- **Possesses good compatibility with most polymers**
- **Is thermally stable (>300°C)**
- **Possesses low volatility**
- **Resists extraction by hot water and detergents**
- **Is odorless and tasteless**
- **Has low oral and dermal toxicity**

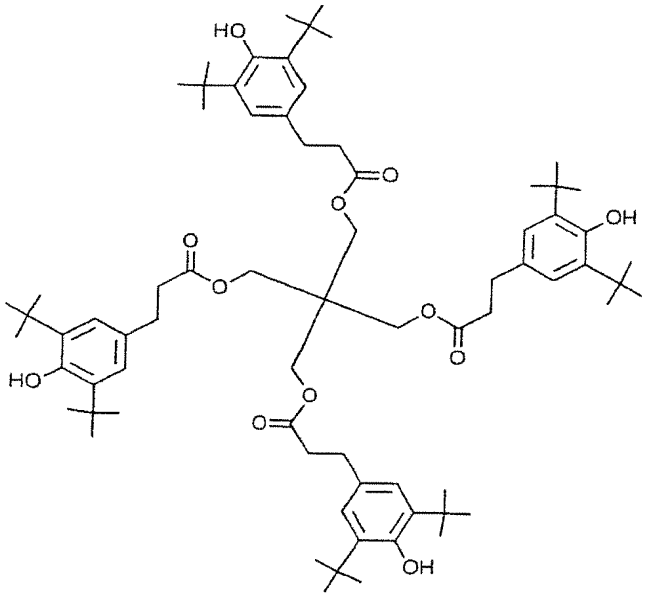
Interpreting Test Data

While the data presented in this brochure are the results of highest quality testing over many years, they are presented here only as an indication of relative performance in a specific polymer system. Other components of a formulation, e.g., pigments and variables such as sample thickness, place and type of exposure, and criteria of stability are all critical and should be considered carefully. We strongly recommend that when making any change or including any additive in your formulation, you test the new system under actual conditions of processing and end-use prior to full-scale manufacture.

Antioxidant and Thermal Stabilizer
Irganox 1010 is a high molecular weight, non-discoloring, non-staining, multifunctional antioxidant. The symmetrical molecule (see chemical structure below) includes four sterically hindered phenolic hydroxyl groups which provide high antioxidant activity.

It is recommended as a stabilizer for organic and polymeric materials subject to thermo-oxidative degradation.

Chemical Structure



Typical Physical Properties

Appearance	White, free-flowing crystalline powder
Melting Range	110-125°C
Specific Gravity	1.15
Molecular Weight	1178

Vapor Pressure
1 x 10^{-6}mm Hg at 100°C
1 x 10^{-3}mm Hg at 200°C

Solubility @ 20°C	**g/100g solvent**
Methylene Chloride	163
Benzene	122
Acetone	89
Chloroform	144
Methanol	0.9
Hexane	0.29
Corn Oil	0.20
Water	<0.01

CAS Number: 6683-19-8
CAS Name: 3,5-bis(1,1-Dimethylethyl)-4-hydroxybenzenepropanoic acid, 2,2-bis[[3-[3,5-bis(1,1-dimethylethyl)-4-hydroxyphenyl]-1-oxopropoxy]methyl] 1,3-propanediyl ester

FDA Name: tetrakis [methylene (3,5-di-*tert*-butyl-4-hydroxyhydrocinnamate)]methane
Empirical Formula: $C_{73}H_{108}O_{12}$

Irganox 1010 is covered by U.S. Patents 3,285,855 and 3,644,482

Antioxidant Thermal Stability
Resistance of antioxidants to discoloration at elevated temperatures is critical, considering the temperature extremes encountered in present-day plastics processing machinery and the repeated exposure to these temperatures caused by the use of regrind material. Irganox 1010 resists discoloration when heated to high temperatures better than many other antioxidants.

POLYOLEFIN APPLICATIONS

Polypropylene
Irganox 1010 is a powerful inhibitor of long term aging effects and an effective processing stabilizer. It is especially recommended for articles with thin cross sections (e.g., films, fibers), in applications where resistance to discoloration is important during both fabrication and service life, in products which must resist deterioration of physical properties during exposure to elevated temperatures, and where resistance to extraction by hot water or detergents is required.

When used as the only stabilizer in polypropylene, Irganox 1010 provides outstanding resistance to thermo-oxidative degradation. Stabilizing effectiveness can be further enhanced when Irganox 1010 is used in combination with thiosynergists such as distearyl thiodipropionate (DSTDP). Table 1 presents a comparison of the performance of four antioxidants in 25 mil polypropylene plaques.

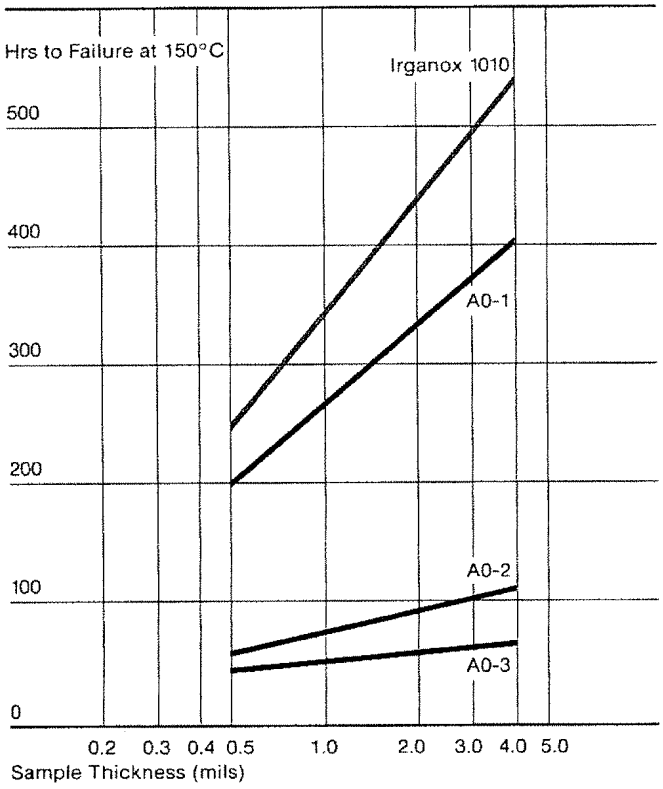
Table 1
Oven Stability of 25 mil Polypropylene at 150°C*

Antioxidant, 0.2%, Concentration	Failure Time, Hr
Irganox 1010	1200
A0-1	1050
A0-4	115
A0-2	45
Antioxidant, 0.1% Concentration + 0.3% DSTDP	
Irganox 1010	2400
A0-1	1980
A0-2	1250

*Polypropylene resin, nominal melt index 4.0, containing 0.1% calcium stearate. Failure indicated by cracking or powdering

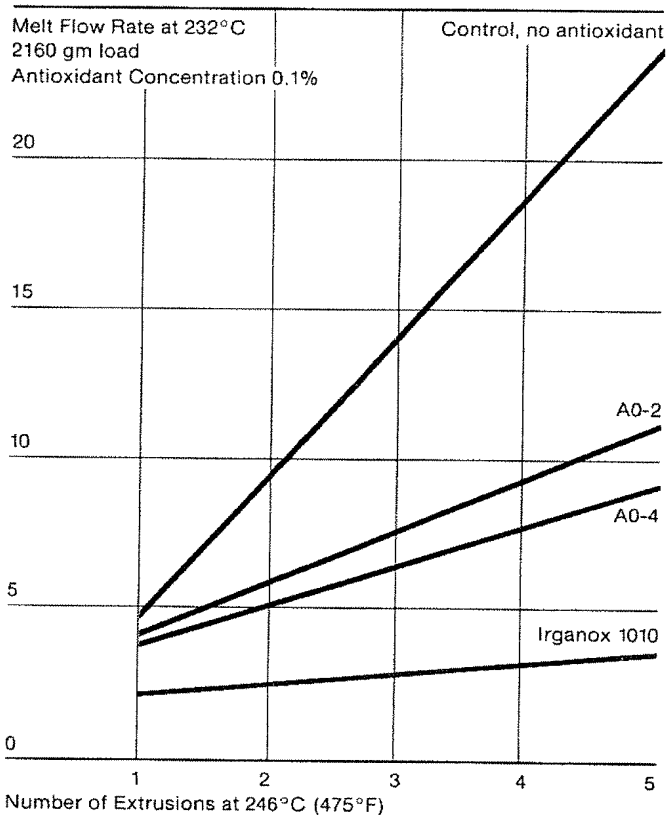
Irganox 1010 exhibits excellent protection in thin cross-section polypropylene articles (e.g., film, fiber). Its effectiveness in thin films containing 0.1% antioxidant and 0.3% DSTDP is shown in Figure 2.

Figure 2
Thermal Stability of Polypropylene



Processing stability is a key factor in the production of polypropylene articles to achieve dimensional stability and uniform mechanical properties. Irganox 1010 protects polypropylene from deterioration during processing as measured by change in melt flow rate on repeated extrusions, as shown in Figure 3.

Figure 3
Processing Stability of Polypropylene



Polypropylene containing Irganox 1010 resists discoloration caused by heat or light, as shown in Tables 2 and 3. Note the very good initial color of polypropylene containing Irganox 1010.

Table 2
Gardner Color* of Polypropylene after Oven Aging at 149°C

	0.5% Antioxidant		0.1% AO + 0.5% DSTDP	
	Initial	100 hr	Initial	500 hr
Irganox 1010	1	3	1	3
AO-1	2	5	1	6
AO-2	2	7	2	6
AO-3	2	3	1	5

Table 3
Gardner Color* of Polypropylene after Fade-Ometer Exposure

	0.5% Antioxidant		0.1% AO + 0.5% DSTDP	
	Initial	200 hr	Initial	300 hr
Irganox 1010	1	2	1	2
AO-1	2	3	1	4
AO-2	2	4	2	9
AO-3	2	3	1	5

*Gardner colors range from 1 (water white) through 18 (dark amber)

Irganox 1010 resists extraction and prolongs the life of polypropylene parts exposed to immersion in hot aqueous media (e.g., dishwashers, washing machines). Table 4 shows the results of a study of the extraction resistance of several antioxidants in polypropylene as measured by hours to cracking/ crazing of plaques before and after 30 days immersion in boiling 1% aqueous detergent solution.

Table 4
Extraction Resistance of 25 mil Polypropylene Containing 0.3% DSTDP

0.1% Antioxidant	Before Immersion Oven Aged at 150°C, Hr to Failure	After Immersion in Boiling 1% Detergent Solution for 30 Days; then Oven Aged at 150°C, Hr to Failure
Irganox 1010	2100	1600
AO-2	1160	910
AO-4	1990	1000

Table 5 illustrates the extraction resistance of Irganox 1010 in knitted polypropylene multifilament.

Table 5
Number of Laundering and Drying Cycles of Knitted Polypropylene Multifilament to Failure

Antioxidant	AATCC Test 4A*
0.5% Irganox 1010	48
0.5% AO-1	18

*AATCC: American Association of Textile Colorists and Chemists. Test conditions: A 45 minute wash cycle at 71°C (160°F) with 0.2% soap, 0.2% sodium metasilicate, and sodium hypochlorite bleach containing 150 ppm available chlorine. The fabric was then dried at 121°C (250°F). This constituted one cycle. Failure was recorded when the fabric could not be flexed without cracking or disintegrating.

Irganox 1010 offers additional advantages. It is stable to at least ten AATCC gas fade (oxides of nitrogen) cycles. The color change during this exposure in polypropylene formulated with four commercial antioxidants is presented in Table 6.

Table 6
Gas Fade Resistance of 3.5 mil Polypropylene (AATCC Test 23-1962)

0.2% Antioxidant	Yellowness Index* Initial Color	(ASTMD-1925) After 10 Cycles
Irganox 1010	1.28	1.17
AO-1	1.37	2.09
AO-2	1.28	2.10
AO-3	1.30	3.23

*Yellowness Index: Higher numbers indicate increasing color.

Polypropylene Copolymer Wire and Cable Insulation
Irganox 1010 enhances the resistance of poly(propylene-ethylene) copolymer wire insulation to thermal degradation, as shown in Table 7. The formulations contained 0.2% of a copper deactivator and 0.2% antioxidant.

Table 7
Thermal Stability of Poly(propylene-ethylene)

Antioxidant	Containing Embedded Copper Screen* Hr to Failure at 120°C
Color, no antioxidant	125
AO-6	140
AO-1	700
Irganox 1035	910
Irganox 1010	1030

*A 10 mil thick copolymer containing an embedded copper screen compression-molded at 216°C (420°F). Failure time was recorded at the onset of either cracking, softening, or discoloration.

Irganox 1010 is also highly effective in stabilization of petrolatum used to waterproof communications cable. Table 8 shows the effect on thermal aging of polypropylene insulated wire containing 0.2% Irganox 1010 and 0.2% of a copper deactivator. Before aging the wires were dipped in petrolatum containing various antioxidants at 0.5% concentration. The insulated wire was then oven aged at 140°C, and time to failure was taken as the first sign of cracking, softening or discoloration.

Table 8
Thermal Aging of Polypropylene Insulated Copper Wire after Petrolatum Treatment

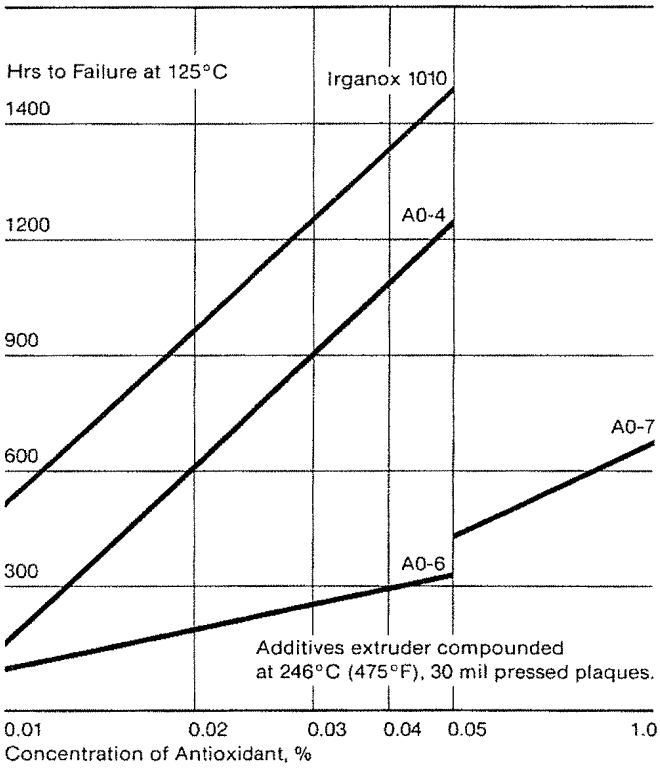
Antioxident Added to Petrolatum at 0.5% Concentration	Hrs to Failure at 140°C
Control, no antioxidant	470
AO-4	470
AO-6	520
Irganox 1010	1050

High Density Polyethylene

For many polyethylene products, resistance to thermo-oxidative degradation during service life is essential. Figure 4 shows that Irganox 1010 effectively protects polyethylene against loss of physical properties on long term aging. Note the high antioxidant activity of Irganox 1010 at low concentration, and how sharply its performance increases with increasing concentration. Figure 5 shows that Irganox 1010 effectively retards discoloration of high density polyethylene aged at 100°C.

Figure 4

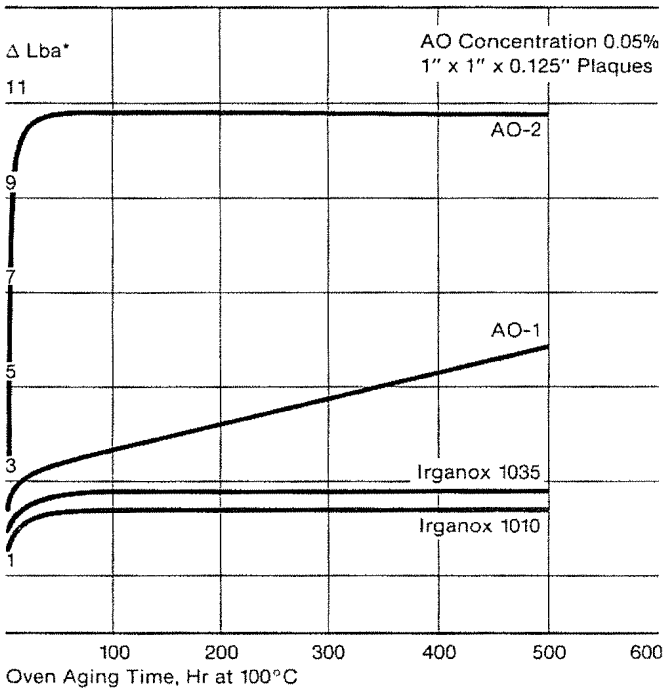
Thermal Stability of High Density Polyethylene (Phillips Type)



Failure times recorded at the onset of cracking/crazing of the sheet upon flexing.

Figure 5

Color Stability of High Density Polyethylene



*ΔLba values represent the color difference between the unaged and the aged samples.

Irganox 1010 is also recommended as an antioxidant for high density polyethylene insulated wire and cable.

Low Density Polyethylene

Irganox 1010 is an effective stabilizer for low density polyethylene film and sheet, as well as for polyethylene insulated wire and cable sheathing. As shown in Table 9, Irganox 1010 retards the thermo-oxidative deterioration of low density polyethylene insulated wire. The formulations contained 0.1% of a commercial copper deactivator, 0.1% antioxidant, and 1.0% TiO_2 pigment.

Table 9

Thermal Stability of Pigmented Polyethylene Insulated Wire*

Antioxidant	Hr to Failure at 80°C
AO-6	790
Irganox 1035	3870
Irganox 1010	4210

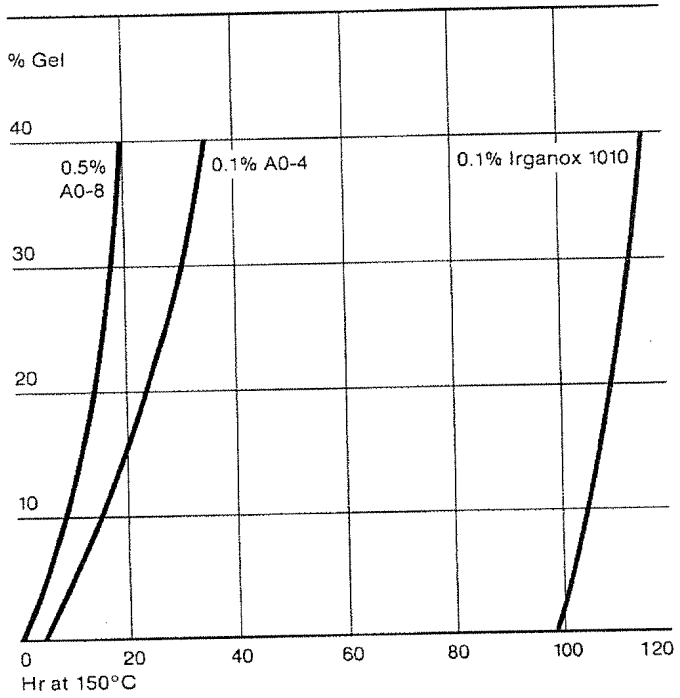
*Wires were aged in a twisted "pigtail" configuration. Failure was shown by one or more of the following changes: discoloration or cracking of the insulation.

ELASTOMER APPLICATIONS

EPDM Rubber

Irganox 1010 inhibits discoloration and gel formation during high temperature drying and storage. It is very effective at low concentrations in 25 mil unvulcanized EPDM plaques oven aged at 150°C, as shown in Figure 6. Color development parallels the gel formation curves.

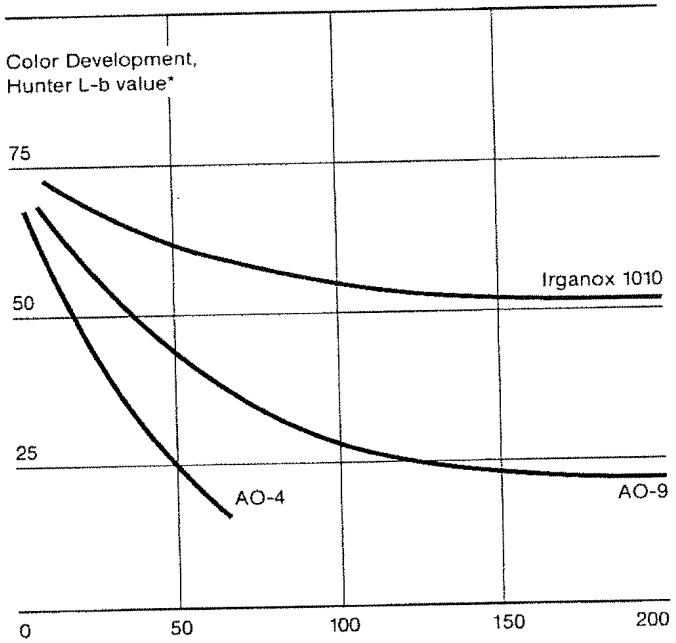
Figure 6
Gel Formation in 25 mil EPDM Plaques after Oven Aging



Thermoplastic SBR Block Copolymer

Irganox 1010 effectively inhibits discoloration of thermoplastic SBR block copolymer as shown in Figure 7. Polymer deterioration on thermal aging is also retarded with Irganox 1010.

Figure 7
Color Stability of 25 Mil Thermoplastic SBR Plaques After Oven Aging



*Higher Hunter L-b values = lighter color

Carboxylated SBR Latex

Carboxylated SBR Latex stabilized with Irganox 1010 exhibits superior heat stability compared with SBR containing other commonly used phenolic antioxidants, as shown in Table 10.

Table 10
Oven Stability of 10 mil Carboxylated SBR Film

Antioxidant*	Hr to Failure at 132°C**
Control, no antioxidant	28
AO-11	30
AO-9	60
AO-12	100
Irganox 1010	450

*0.5% Antioxidant (based on rubber solids). Formulation contains 122.5 phr calcium carbonate.

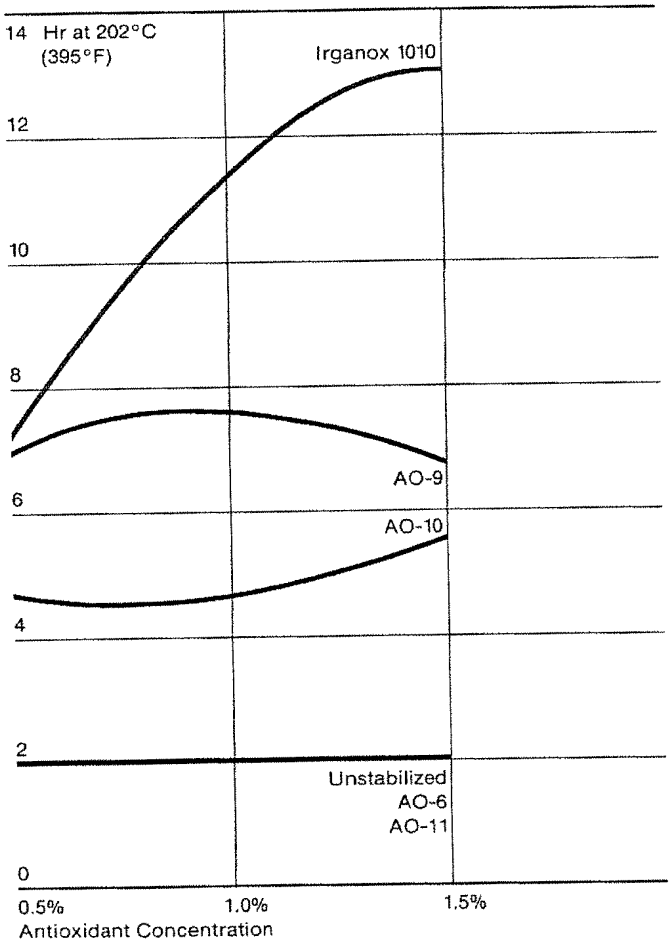
**Failure time was taken as initial embrittlement of the film upon flexing.

Adhesives Applications

Irganox 1010 retards "skinning," viscosity increase and color development of hot melt adhesives based on polyesters, polyamides or ethylene vinyl acetate when these products are heated to operating temperatures for long time periods. Irganox 1010 effectiveness increases markedly with concentration up to 1.0%, in contrast to other antioxidants which do not show this effect. Figure 8 shows the effect of antioxidant concentration on time to initial skin formation of a low molecular weight polyamide maintained at 202°C (395°F). The viscosity of this system is also stabilized at this temperature with the use of Irganox 1010.

Figure 8

Effect of Antioxidant Concentration. Time to Initial Skin* Formation, Low Molecular Weight Polyamide.



*"Skin" is defined as a tough, oxidized surface film.

PETROLEUM PRODUCTS

Irganox 1010 inhibits oxidative breakdown of lubricating fluids exposed to high thermal environments, e.g., gas tubine oils. Table 11 illustrates the performance of Irganox 1010 in a mineral based turbine oil during thermal aging.

Table 11

Oxidation of a Mineral Based Turbine Oil at 110°C. Modified Staeger Oxidation Test

Antioxidant	Failure Time, Hr*
Control, no antioxidant	365
1.0% AO-11	690
0.5% Irganox 1010	1250

*Antioxidants were dissolved in the oil by heating until solution occurred. The oil samples were placed in a beaker containing strips of copper foil and oven aged. Failure was recorded as the time to reach an acid number of 0.2.

Irganox 1010 is also suggested as an antioxidant for synthetic diester fluids, and for oils, fats and waxes.

Other Applications
It is suggested that Irganox 1010 be evaluated as an antioxidant for higher α olefin polymers and copolymers, e.g., polyisobutylene, polybutene-1, and poly(4-methylpentene-1).

Evaluation of Irganox 1010 is also recommended in polyamides, polyesters, fiber finishes, styrenic polymers, including rubber-modified types, ABS, polyacetal, poly(vinyl chloride), polybutadiene and polyisoprene.

Food Packaging Applications
Irganox 1010 may be used in all polymers for food packaging applications, subject to the provisions of Title 21, Code of Federal Regulations, Section 178.2010.

Olefin polymers
Ethylene—methacrylic acid copolymers
Ethylene—acrylic acid copolymers
Isobutylene polymers
Ethylene—vinyl acetate copolymers
Polystyrene and rubber—modified polystyrene
Polyoxymethylene, homopolymers and copolymers
Poly-1-butene resins and butene/ethylene copolymers
Styrene-butadiene copolymers used in compliance with provisions of Subpart F of Section 121.

Irganox 1010 may also be used as a component of adhesives for food packaging applications, as provided for in Section 175.105 of the above Code.

Pressure sensitive adhesives
Resinous and polymeric coatings
Resinous and polymeric coatings for polyolefin films
Components of paper and paperboard on contact with aqueous and fatty foods
Defoaming agents used in the manufacture of paper and paperboard
Closures with sealing gaskets for food containers
Preservatives for wood
Reinforced wax

The above is an abbreviated listing of FDA clearances for Irganox 1010. Please consult the current *FDA Status of CIBA-GEIGY Additives* for FDA numbers and restrictions and for possible additional clearances.

Safety and Handling
This product is not considered to be a hazardous chemical under the OSHA Hazard Communication Standard (29 CFR 1910.1200).

Real Material Safety Data Sheet before handling.

Key to Antioxidants Mentioned in this Bulletin

AO-1	1,3,5-Trimethyl-2,4,6-tris (3,5-di-tert-butyl)-4 hydroxybenzyl) benzene.
AO-2	1,1,3-Tris-(2-methyl-4-hydroxy-5-tert-butylphenyl)butane
AO-3	4,4'-Butylidene bis (6-tert-butyl-3-methyl-phenol)
AO-4	Tris (3,5-di-tert-butyl-4-hydroxybenzyl) isocyanurate
AO-5	Commercial mixture of alkylated cresols
AO-6	4,4'-Thiobis (6-tert-butyl-3-methylphenol)
AO-7	2,6-di-tert-butyl-4-methylphenol (60%)/ dilauryl thiodipropionate (40%)
AO-8	Commercial mixture of tris-nonylphenyl phosphite and styrenated cresols.
AO-9	2,2'-Methylene bis (4-methyl-6-tert-butyl-phenol)
AO-10	4,4'-Methylene bis (2,6-di-tert-butylphenol)
AO-11	2,6-di-tert-butyl-4-methyl-phenol
AO-12	4,4'-Isopropylidene bis (5-methyl-6-tert-butylphenol)

Important
These materials will not be sold for use in products for which prolonged contact with mucous membranes or abraded skin, or implantation within the human body, is specifically intended. Because of the wide range of such potential uses, CIBA-GEIGY Corporation is not able to recommend these materials as safe and effective for such uses and assumes no liability for any such uses.

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